Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

edge of the character and chemical composition of the rocks of the moon, and thus possibly a decision of the question of the volcanic or non-volcanic origin of its "craters," might conceivably be arrived at by astronomers, through study of the maximum polarization angle of various portions of the moon's surface, such as the floors of the "seas" and the "walled plains." From the determination of this, calculation of the index of refraction of the material is a simple matter. The difference between the refractive index of a rhyolitic glass (*ca.* 1.490) and that of a basaltic glass (*ca.* 1.590) is so great that it would seem to be possible to obtain some general or at least roughly approximate knowledge of the general composition of the surface rocks of the moon, especially if they are glassy lavas. We should be able, in any case, to determine thus whether all parts of the moon's surface are composed of the same material.

AN OUTLINE OF GEOPHYSICAL-CHEMICAL PROBLEMS

By Robert B. Sosman

The subject-matter of geophysical-chemistry may be defined as "the physical properties and chemical reactions of the substances and aggregates that make up the earth". It may therefore be roughly divided into two parts: A. Properties and reactions of materials accessible at the earth's surface. B. Properties and reactions of materials in the earth's interior.

Each of these may again be sub-divided as follows:

1. Properties and reactions of individual chemical substances; for example, the silicate minerals.
2. Properties and reactions of aggregates; for example, oceanic water, silicate rocks.
3. Properties and reactions of larger units of matter; for example, glaciers, batholiths.

A. MATERIALS AT THE EARTH'S SURFACE

Chemical Substances

A relatively small number of "common" oxides serves to make up practically 98% by weight of the outer ten miles of the lithosphere. All the other elements and compounds known to chemistry are included in the remaining 2%. From the geochemical standpoint, therefore, we may divide chemical substances into two classes: "abundant" and "rare."

The "abundant" oxides are, in the order given by averages of a great many analyses of terrestrial rocks, as follows:

SiO_2	About 60 per cent by weight
Al_2O_3	About 15 per cent by weight
FeO Fe_2O_3	About 6 per cent by weight

CaO	About 4.9 per cent by weight
MgO	About 3.7 per cent by weight
Na_2O	About 3.3 per cent by weight
K_2O	About 3.0 per cent by weight
H_2O	About 2.0 per cent by weight
CO_2	About 0.7 per cent by weight

An understanding of the chemistry of these oxides and their combinations is essential to the progress of petrology. Their study should proceed from the simple to the complex, i.e., should begin with the individual oxides, then proceed to their two-component systems, then the ternary systems, and so on. Upon this fundamental basis is then erected the structure of physical properties for each system: densities at all accessible temperatures, mechanical properties, fluidity, surface tension, specific and latent heats, etc.

The study of these systems may be divided on practical grounds into (1) investigations of the anhydrous oxides and silicates (taking in the first eight oxides in the list above); (2) investigations involving *hydrous* silicates, as well as combinations containing both carbon dioxide and water.

(1) *Anhydrous Silicates.*—Work on the first group involves high-temperature researches under ordinary atmospheric pressure conditions, except in the case of systems containing the oxides of iron, where the oxygen pressure must be controlled, and systems containing the alkali silicates, where attention to moisture, carbon dioxide, and volatility of the oxides is necessary in certain cases. Considerable progress has been made in the study of the anhydrous silicates. The phase rule diagrams of the four ternary systems of SiO_2, Al_2O_3, MgO, and CaO are now complete, and a large amount of data is at hand on the alkali feldspars, the forms of silica, portions of several quaternary silicate systems, etc.

(2) *Silicates with Volatile Components.*—Work on systems involving the volatile components CO_2 and H_2O must be done, for the most part, under pressure, and with apparatus designed especially for this purpose. The methods are well in hand and progress is being made in assembling experimental data. The theoretical side, involving the complications due to pressure as a variable in addition to temperature, is also being carried forward by several investigators.

So much for the 98%. But the remaining 2% contains many natural substances of such great economic as well as geologic interest that they must also receive attention. These may be roughly classified as in the following examples:

The Sulfide Ores (e.g., sulfides of iron, nickel, zinc, copper, lead, cobalt, cadmium, mercury, silver).—These must be studied both in their dry melts (to obtain their fundamental characteristics) and in relation to water solutions under atmospheric pressure (problems of oxidation and secondary enrichment). A distinct problem of the sulfides is their relation to the silicates in the igneous rocks (differentiation of sulfide-bearing bodies, as at Sudbury, Ontario).

Volcanic Gases and Salts.—These are of particular interest in their relation to volcanic activity, as at Kilauea and Vesuvius. Research on gases, including the various gas mixtures evolved from volcanic vents, is of a peculiarly trying character on account of the invisibility and intangibility of the substances handled, as well as the difficulty of collecting and transporting samples of the natural products. A special phase of this work is the study of the complex gases given off by fumaroles and hot springs. In addition to chemical composition and equilibria of the gases, data are needed on the physics of the flow of such gases from vents, as related to volume, temperature, and pressure at the point of emission.

The volcanic "sublimates", such as sulfur, ammonium chloride, arsenic sulfide, copper chloride, magnetite, may be mentioned in this connection, as well as the minerals accompanying fumarole and hot-spring activity.

The Oxide Ores (e.g., ores of iron, chromium, manganese, tin).—The study of these ores involves high-temperature investigations similar to those on the silicates, and also studies of the hydrated and colloidal oxides.

The Natural Hydrocarbons.—Organic chemistry of a very complex kind is involved in the formation and alteration of natural gas and petroleum, and many problems of physics and physical chemistry, such as adsorption, surface tension, and colloid phenomena, are also involved in their underground storage and movements.

Other substances—for example, the silicate ores, the carbonate ores, the titanium minerals—may be similarly grouped for purposes of experimental study, but it is hardly necessary here to make a complete inventory of such groups.

Running along with all these investigations is the general research necessary to develop experimental methods and apparatus, and to keep the general theory of physics and chemistry abreast of the newly accumulated facts.

AGGREGATES

In the preceding paragraphs we have mentioned some of the researches that are necessary on the chemical *substances* of the earth's surface. We come next to *aggregates*, including the igneous rocks, the pyroclastic and sedimentary rocks, the oceans and other bodies of water, and the atmosphere.

Igneous Rocks and Magmas.—Among the aggregates the igneous rocks are the most important, constituting as they do the original matter from which the others have been derived. They are poly-component systems with seldom fewer than six oxides, and it seems out of the question at present to give a complete phase-rule discussion of the chemistry of any such complex system. It does seem possible, however, to cover the field of actually occurring rocks by partial systems based upon stable minerals, themselves combinations of two or more oxides.

Experimental work has progressed far enough to show that the fusion and solidification phenomena of the igneous rocks are capable of systematic treatment of the kind mentioned above, even when the volatile components H_2O and CO_2 are included.

Following this fundamental information on the fusion diagrams, we must know the densities of the igneous rocks and their magmas at all temperatures, with their changes of volume during solidification; the textures and structures produced by various conditions of solidification; the latent heats concerned in fusion of the magma and in assimilation by it of other rocks; and many other physico-chemical data.

Some of the phenomena of differentiation of silicate rocks are probably to be treated as results of simple crystallization backed up by the effects of gravity in causing sinking or flotation of crystals. This is the only method of differentiation that has been experimentally proven, but the separation of two or more liquid phases, and perhaps other phenomena also, may take part in this little-known process.

The phenomena of the movements of igneous magmas in the lithosphere must next be attacked. This involves studies of viscosity and its changes with temperature; energy transfers accompanying movement, including perhaps the conversion of potential gravitational energy into heat energy by movement; differentiation due to movement; and the effects of the separation of gaseous constituents in causing differentiation, movements of magmas, and transfers of energy.

While the igneous rock is solidifying, processes of metamorphism may go on as a result of the passage of its more volatile constituents through the igneous rock itself and through its bordering rocks. The rise of temperature in the inclosing rocks will also initiate reactions and movements of material. The chemistry of these processes (alteration, serpentinization, contact metamorphism and replacement, formation of pneumatolytic dikes and veins) will have been included under the chemistry of the silicates with volatile components, but the rates of the reactions and the transfers of energy accompanying them must be studied as a separate problem. The question of the permeability of crystalline substances to volatile components may perhaps arise. Studies of the inversion of polymorphic forms, properties of liquid inclusions, and the effects of increased temperature on neighboring rocks must be made in order to obtain data on the original temperature of the magmas.

Sedimentary Rocks.—No sooner does the solidified igneous rock find itself at or near the earth's surface than it becomes the object of the group of processes known as "weathering." This is a subject that has been nearly at a standstill since the publication of Merrill's "Rocks, rock weathering, and soils" about fifteen years ago, which summarized our knowledge up to that date. It involves physical factors such as the disintegrating action of periodically fluctuating temperatures, together with the study of relative rates of reaction within and in the presence of dilute water solutions, with the complications due to colloidal phenomena and reaction in capillary spaces—a difficult field and one worthy of well-planned effort.

Rock disintegration, corrasion, and transportation, included in the general process of erosion, bring in physical and mechanical problems such as the rounding of fragments by attrition; their sorting by air and water movements; their distribution and redistribution through the agency of winds, currents, and waves; the production of particular structures such as ripple marks; the movement of unconsolidated sediments as in sand dunes, soil creep, and solifluxion; and similar questions. Reference need only be made here to summaries of these problems by Vaughan and by Merwin before the Geological Society of America in December, 1919. Experimental physics will be found deeply involved in all such problems. Colloidal chemistry will also enter, as, for instance, in the question of the precipitation and re-solution of fine suspensions; likewise biological chemistry, in the precipitation and consolidation of calcium carbonate, ferric oxide, and other products associated with organisms.

Chemical questions allied to those of weathering will enter into the problems of the consolidation and alteration of sedimentary rocks, including cementation and recrystallization, the formation of low-temperature veins, silicification, and the growth of concretions. The elastic constants of porous aggregates offer an example of the physical data that are likely to be needed in this same connection.

Pyroclastic Rocks.—The question of the origin of these rocks brings up the problem of explosive volcanism. In its larger aspects this belongs properly to the Section of Volcanology, but the products of this type of volcanic activity are very wide-spread, and the particular physical and chemical questions arising from the state of subdivision and modes of distribution and alteration of the products deserve special mention in this rather rough grouping of geophysical-chemical problems. Examples are: the molecular mechanism of the explosion, the peculiar properties of flowing dust-clouds, the physics of the projection of volcanic bombs, the sorting of products by air currents and the weathering of "ash" to form colloidal products.

The Metamorphic Rocks.—The point where a rock ceases to be "igneous" or "sedimentary" and becomes "metamorphic" is not now exactly defined, though subject to exact definition, but a distinct set of physical and chemical questions undoubtedly enters into the problems of dynamic and thermal metamorphism. The effects of *non-uniform* pressure in causing the flowing of crystalline substances and aggregates and their solution and redeposition, as well as the forces exerted in their recrystallization, are of particular interest. The structures resulting from movement in silicate rocks under differential pressure are in need of quantitative study. Transfers of mechanical energy and its conversion into heat are also involved. Consolidation and recrystallization as a direct result of *uniform* pressure are likewise to be considered.

Mention should be made in this connection of the physics and chemistry involved in faulting as well as in jointing and minor movements of the solid rocks. These phenomena have often been treated under the principles of elastic theory as applied to homogeneous bodies, yet there can be no question that the elastic properties and conditions of rupture of aggregates must differ in many essential particulars from those of homogeneous bodies. Here is a considerable field for experimentation.

Bodies of Water and the "Chemical Sediments".—The chemistry of the deposition of salts from sea-water has already been made the subject of special research, and van't Hoff's results in this field are already familiar. The deposition of calcium carbonate awaits a similar thorough study. Allied questions are the formation of dolomite, the deposition of various salts from inclosed bodies of water, the deposition of phosphate rocks, the precipitation of colloidal suspensions of clay and other substances, and the origin of the great deposits of sedimentary iron ore.

Problems of fresh-water bodies and streams include the chemistry of bog iron ores, and the amounts of insoluble and colloidal solids and of soluble salts carried by streams. Problems relating to underground waters may also be included here, such as: the dissolving and recrystallizing activity of underground waters; connate waters and their possible chemical changes; movements of underground waters and their relation to the alteration and concentration of gas and oil; principles of hydraulics governing the flow of wells and springs; and the characters which will serve to differentiate between vadose and juvenile waters.

The Atmosphere.—The physics and chemistry of the atmosphere considered as a chemical unit or aggregate, while logically a part of geophysics and geochemistry, are usually considered to be part of the province of meteorology; and in fact most of the investigations in this field are being made by meteorologists, or physicists employed in meteorological organizations. These questions will therefore not be further considered here. Data bearing on the origin of the earth's atmosphere and its possible changes of composition in the past—for example, the composition of the gases found in rocks and the gases dissolved by the waters of the oceans—are, however, of direct interest to the present Section.

LARGER UNITS

The larger units of matter at the earth's surface are for the most part covered by other Sections. The atmosphere as a unit is treated by the

Section of Meteorology and the atmospheric-electric branch of the Section of Terrestrial Magnetism and Electricity; the oceans by the Section of Physical Oceanography; the large land masses by the Section of Geodesy; volcanoes as units by the Section of Volcanology.

The larger geologic units (for example, petrographic provinces) and the rocks, considered as geologic units, might be considered to fall within the province of geology rather than geophysics, and the same may be said of the earth's glaciers and ice-sheets.

There are certain problems connected with these larger units, however, that may be neglected by the Sections mentioned, not from any lack of appreciation of the importance of the problems, but solely by reason of lack of training and lack of acquaintance on the part of their personnel with the technique involved; just as some of the geophysical-chemical problems mentioned above may be, relatively, neglected by reason of the geophysical-chemist's lack of training in other branches. For example, the physics of the flow of a glacier, considered as a unit, is not likely to be adequately handled by those trained only in the methods of glacial field geology, and it very properly becomes a subject for research under the present Section. The question of the chemical composition of a particular stratum of the atmosphere and the chemical equilibrium obtaining therein, while of great importance to the meteorologist, might fail of adequate treatment by an organization numbering no chemist on its staff. The distribution of certain rock-forming oxides according to "petrographic provinces" may be of primary interest to the geologist, yet the physico-chemical basis for that distribution—the question whether it represents an "original heterogeneity" or a result of differentiation—is a problem for this Section. The flow of rock aggregates of varying composition, again a matter of geological interest through being concerned in the processes of mountain-building, is a problem for the geophysicist. These examples will serve to indicate that there may be many points in which the Section of Geophysical-chemistry may be of direct assistance, through researches of its own type, in the work of other Sections.

B. PROPERTIES OF MATERIALS IN THE INTERIOR OF THE EARTH

The late G. K. Gilbert has made apt reference[1] to the earth's interior in these words: "Once it contained the forges of blacksmith gods; or it was the birthplace of our race, or the home or prison of disembodied spirits * * * * Science now claims exclusive title but holds it chiefly for speculative purposes." Upon the Section of Geophysical-chemistry more than upon any other will fall the duty of maintaining the validity of the title while bringing the property into productive use.

The outstanding difference of condition to which substances in the earth's interior are subjected, as contrasted with substances at the surface, is the tremendous difference in hydrostatic pressure. Research on the properties of substances under high pressure is thus of first importance in relation to the interior of the earth. While we cannot at present go experimentally much beyond 12,000 megabars, a pressure corresponding to about 45 km. (about 29 miles of depth), yet a really adequate knowledge of properties in this range would give us an insight into the conditions in the interior beside which our present knowledge is equivalent to almost total ignorance.

It is most important to know in this connection the compressibility of the substances concerned, at various temperatures, and in both the liquid and the crystalline state, with its dependent constants such as change of melting-point with pressure, and effect of pressure upon solubility. Other important data are: the existence of new polymorphic forms of substances; the effect of pressure upon rigidity and its related elastic moduli; the effect of pressure upon diathermancy, thermal conductivity, specific heat capacity, and magnetic susceptibility; and the effect of pressure in modifying equilibrium in homogeneous as well as heterogeneous systems.

The properties mentioned in the preceding paragraph are all properties of substances in equilibrium. The effect of pressure upon rates of reaction and rates of diffusion and crystallization are also of importance. If the planetesimal hypothesis of the origin of the earth, or some modification of it, is true, it is possible that the interior is very far from a state of chemical equilibrium, and that redistribution of matter and energy may be going forward actively, with what results—whether rising or falling average temperature, increasing or decreasing volume, etc.—it is impossible now to say.

The preceding considerations apply also to the larger units of structure of the interior—although what these units may be we can only guess—and also to the earth itself as a unit. Complex mathematical analysis is necessary in applying the data to the units of structure as well as to the whole of a body as large as the earth, where the force of gravitation is itself variable with depth. These applications can in many cases be best made by those familiar with the properties in question as measured in the laboratory. The course of earthquake waves, to take an example of interest to the Section of Seismology, is dependent both upon the elastic constants of the earth's materials, and the possible reflection and refraction of waves at the boundaries of internal structural features.

In this connection, the members of this Section could do a service to the other Sections by making clearer the real meaning of some of the physical concepts and physical constants involved in geophysical problems. For instance, much confusion has been caused by the fact that there is more than one kind of "rigidity". The geologist to whom the statement that "the earth has the rigidity of steel" is rather vague may take temporary comfort from the fact that the statement also needs much qualification and explanation to the physicist.[2]

General Geophysics.—The physics of the earth considered as a unit (the classical "geophysics") is for the most part either covered by other Sections of the Geophysical Union or is customarily considered as a part of geology. Certain phases of geophysics, however, are not thus assignable and may be mentioned here in order that all of the groups of problems of the science may receive attention in this assembly of surveys.

The form and gravitation relations of our suspended spheroid, its magnetic and electrical properties, its properties as a vibrating body, and the physics of its air and water envelopes, are the obvious fields of appropriate Sections. Hypotheses of its origin and the logical deductions therefrom may confidently be left to the geologists, among whose faults that of narrow-mindedness and lack of a broad outlook in time and space have seldom been numbered.[3] Its properties as an absorbing and reflecting body for external radiation are being well handled by the astrophysicists and meteorologists.

The problem of the earth as a body radiating its own heat into space, however, is an example of a problem that may fail of treatment as a unit problem by any one of the above-mentioned groups acting alone. We are dealing not with a solid homogeneous spheroid of uniform surface temperature radiating freely into space, but with a rather heterogeneous body blanketed with several kinds of heat insulators whose composition varies both with depth and with time. Factors in the problem are: the production of heat by shrinkage; the contributions of heat from radioactive sources; the earth's present thermal conductivity and thermal gradient; the effect of varying carbon dioxide, water, ozone, inorganic dust, and clouds, upon the heat loss; and the effects of the possibly very different atmospheres with which the earth has been blanketed in past ages. The temperature at a given time and at a given distance from the center, as for instance at the solid surface of the land, depends upon a complex set of factors, and may well have been periodic in its variations.

The earth's volume and shape may have been similarly variable. In addition to the variation of temperature, already mentioned, the following are among the factors to be considered: the tides in the solid earth (on which extensive experimental work has recently been in progress) and the earth's properties as an elastic body; the viscosity of the earth as a whole, with relation to long-continued forces, and the existing state and method of maintenance of isostatic equilibrium in its surface layer; its breaking strength and form of rupture under forces changing too rapidly to cause flow; and the lag of elastic and viscous responses to changing forces, as in the case of the addition or removal of continental ice sheets.

Limitations of space forbid more than a sketchy outline of the problems set before the Section of Geophysical-chemistry, but it is hoped that the outline may have been sufficient to indicate the very fundamental character of those problems.

GEOPHYSICAL LABORATORY,
CARNEGIE INSTITUTION OF WASHINGTON.
June, 1920.

---

[1] U. S. Geol. Survey, *Prof. Paper* **85C,** 1913 (35).

[2] See Lambert, *Journ. Wash. Acad. Sci.,* **10,** 1920 (122–143).

[3] In this connection it is important that the study of the composition and probable sources of the matter now being received by the earth, in the form of stony and metallic meteorites, be continued and extended.

THE IONIZATION OF STRONG ELECTROLYTES

BY WILLIAM D. HARKINS

KENT CHEMICAL LABORATORY, UNIVERSITY OF CHICAGO

Communicated by J. Stieglitz, April 14, 1920

It is well known that in all branches of knowledge it is sometimes difficult to express certain thoughts with accuracy on account of the fact that the meaning of words changes. So in science there are periods when either the same words have a dissimilar meaning, or unlike words have the same meaning, to different workers. This sometimes becomes so marked that old hypotheses may seem to disappear, or new ones to appear, when only the significance of the technical terms has undergone a change. In other cases old terms may be used in new ways to suggest valuable new points of view.

The recent paper by A. A. Noyes and D. A. MacInnes in these PROCEEDINGS[1] which supports the idea of Sutherland,[2] Milner,[3] Ghosh,[4] and Bjerrum,[5] that strong electrolytes are completely *ionized* in solution, may be considered as belonging to the last category. They use the term ion in the sense of a charged particle, and not as a charged particle which is free to move in the electric field, which is the older meaning of the term as applied to solutions, though it must be admitted that their use of the word is in harmony with the meaning attached to it in recent papers in physics. However, it is not the terminology, but the idea it is apt to convey to workers in various fields, which is to be the subject of attention in this short note. The idea developed by Bragg, that a solid salt consists not of a collection of molecules, but of atoms, has led to the